SAVING THE CROPS FROM INJURY BY FROST

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"A penny saved is twice earned" said Franklin, and one can not help wondering what that wise old gentleman would say today about food conservation and especially the problem of saving crops from injury by frost. Throughout Christendom at the present moment the uppermost topic of discussion is food. Apparently the outcome of this great war will be largely determined by the supply of food. In our own land as well as in other lands every effort has been made to increase the crop yield by adding to the acreage and by intensive cultivation. Fertilizers have been used as never before, farming operations go on by night as well as by day, tractors do the work of many horses, and in every direction there is intense striving for big harvests. Those of us who are not in the field do our bit by lessening the demand, practicing economy, and preventing waste. Is it not wise, then, to study natural wastage in all its forms? For Nature herself is the master spendthrift; and the yearly losses through natural conditions, such as droughts, pests, and frosts, easily exceed the savings of the community for a long period.

Now, if ever, is the time when every effort must be made to reduce the losses by frost. The problem is one in the geography of the lower air, or, in other words, frost is largely a matter of *local air drainage*. Frost can be mastered and, indeed, has been mastered in some localities.

The word "frost" has been used in three different senses: first, a freezing temperature; second, the spicular ice crystals; and third, the damage resulting from defrosting or frosting. The first is an erroneous usage and should be abandoned. The second interests the aërographer, or student of air motion and physics, while the third, which is the proper usage, interests the plant physiologist and the public. When water vapor in the air near the ground changes its form directly into ice we get the familiar spicular or pointed crystal which most of us call frost. It does not go through the intermediate state of being water, else frost would be frozen dew, and all the flakes would be little globes. After a still, clear cold night, with neither too much nor yet too little moisture present, we find next morning crystals covering the grass and lower foliage, and most of us think, if the deposit is at all heavy, that much damage has been done. If later the plants shrivel and blacken we think that the crystals did the mischief. On the contrary, Nature, through the agency of these crystals, was trying to cause a delay or lag in the cooling. By this very same method, which we shall later explain, namely the utilization of the fact that ice has a high specific

heat compared with that of air, delicate flowers may be saved in freezing weather. It may run counter to our established notion to say that frost crystals protect vegetation from injury, but they do. The destructive factor is the fall in temperature and the consequent expansion and contraction of the plant tissue and juices in opposite directions. More frequently

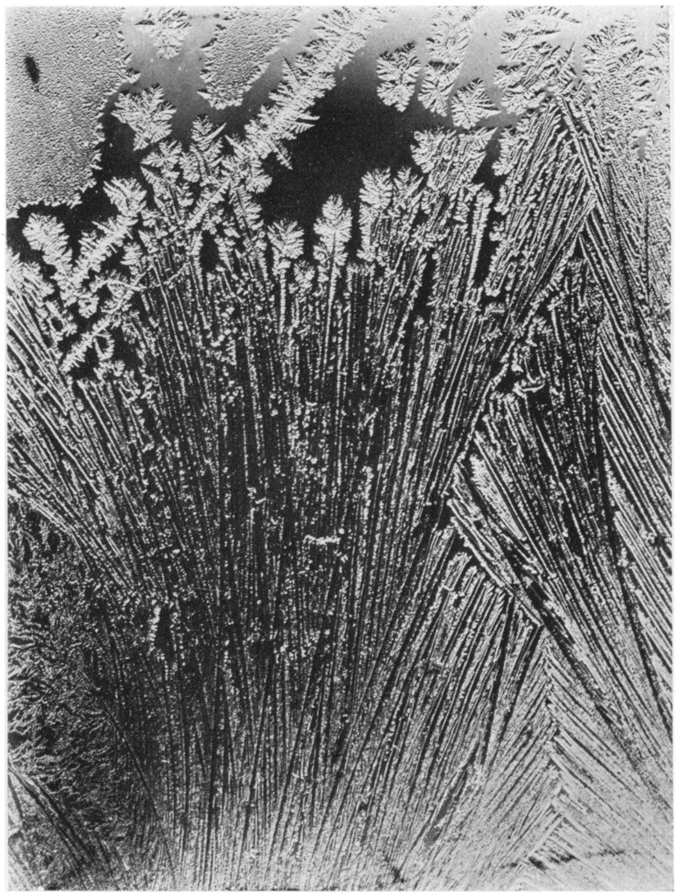

FIG. 1—The symmetrical beauty of frost lines. (All the illustrations are from photographs by the author.)

still the damage is due to a sudden rise in temperature after refrigeration. Probably it is the strain to which cells are subjected by rapid warming after chilling which does most of the damage known as frosting. It is not the freezing but the thawing which works the mischief. The writer found in the orange groves of California that in two hours the rise in temperature might amount to ten or fifteen degrees, i. e., at a rate far exceeding that at which the temperature fell, and, what was still worse, the upper side of an orange would be warm and the under side still frozen. The

damage was nearly always greatest where the fruit was freely exposed to the rays of the rising sun, and, other things being equal, a southeastern exposure was the worst. The remedy is cold water or a light smoke cloud, for we must check the sudden rise in temperature.

How shall we prevent or minimize the damage? We can do this, but not without some effort and at some expense. The fight, however, is worth

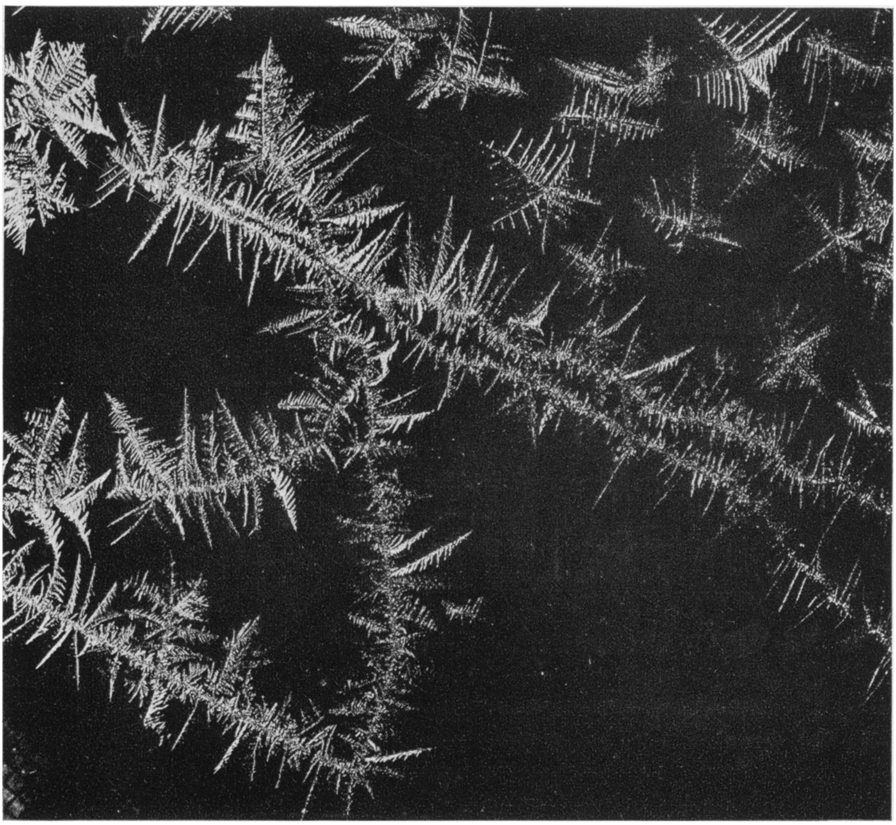

FIG. 2—Frost spicules, twice actual size.

while, as has been proved by the campaigns in the great fruit belts on the Pacific Slope. A brief review of what has been done in California will encourage the doubters.

One day in December, 1895, the general forecaster at San Francisco issued warnings of frost. The press of the orange belt made merry over the warning, but, to their surprise and discomfiture, the frosts came and the losses were heavy. A few horticulturists in Riverside met to talk over the situation and the forecaster was called in for consultation. Within a month one of the members had designed and tried out a wire basket, suspended about three feet above the ground and holding about ten pounds

of coal with the necessary kindling. That was the first of modern frost protectors, the Copley coal basket.[1] Other members tried movable smudgers and heated water suppliers, and on one ranch a covering of laths was tried, which, although expensive, proved its worth. A few years later came the first oil burner for use in the vineyards near Fresno, and from this all the present forms of orchard heaters have been developed. Eighteen years later, during the first week in January, 1913, the same forecaster had occasion to issue frost warnings, but with very different results, for the press spread them far and wide, leaving no stone unturned in urging the growers to smudge and fire *early*. It was necessary, for there followed the severest weather ever known in that section; and the battle was fairly joined between Nature and Man. Man won. There were plenty of thrilling experiences in this fight, and much could be told if time and space permitted. Moreover, in this war between man and nature there can be no end, for the fighting must be renewed as long as the seasons come and go.

How does the forecaster know that frost is coming? Chiefly by anticipating for the given localities a certain type of air flow or circulation near the ground, and which is largely determined by the lay of the land. To the general movement of storm areas and the accompanying winds he must add the cumulative effect of much gentler currents, so slow indeed that they might be called "creeping" currents. When a barometric depression, or "low," as it is called, moves briskly eastward and is followed by an anticyclonic circulation, or "high," as shown by the surface isobars, the latter will at certain times seem to settle down and stay quiescent for sixty or more hours. A stagnant "high" gives results quite different from the ordinary interchange of air. There is an absence of convectional currents; there is no mixing of the different layers of air; and, to use the term of a foreign meteorologist, there is no *churning*. This lasts for two, three, and sometimes four days and nights. It is easy to see now why frosty nights follow one another, why we seldom have more than three frosts in succession and why the last night may have the lowest temperature. It is also plain why still nights are frost nights and why there are no clouds, because whatever currents there are, are from above downward rather than upward. And finally the air, since it comes from above, is dry and pure, that is, free from dust and haze; and, while perhaps slowly heated by compression in falling, still it is not heated enough to overcome the chilling which follows from contact with the cold ground. And the ground goes on cooling all the more rapidly because the air is very pure and dry. Marked inversions of temperature take place, the cold air is down and can not get up and the warm air is up and can not get down. As a result of the slow side drainage, shallow ponds of stagnant air are formed. The forecaster who has, besides his air maps, topographic maps, can follow the cold air down into

[1] For a variety of frost-protecting appliances see the illustrations in W. G. Reed: Protection from Damage by Frost, *Geogr. Rev.*, Vol. 1, 1916, pp. 110-122.—EDIT. NOTE.

FIGS. 3 and 4.

FIG. 3—The Frost King. Skiron, the northwest wind, is the driest that blows at Athens. This wind is extremely cold in winter, but in summer it is scorching, violent, and accompanied by frequent and blinding flashes of lightning; it does great mischief to vegetation and affects the health of the inhabitants. There is an air of languor in the countenance of this figure; his upper tunic is short and has sleeves which reach to the wrist; the vase he holds is of a form quite different from the water jar in the hands of Notos; it is curiously wrought and probably represents a brazen fire pot from which he may be supposed to scatter ashes and burning coals. In the United States frosts, as a rule, follow a period of gusty northwest wind, which lulls at the approach of night.

FIG. 4 The Frost Protector. Notos, the south wind, is sultry and very wet. The sculptor has represented this wind by the figure of a young man emptying a jar of water. In the United States a south wind, as a rule, obstructs formation of frost.

Figures 3 and 4 are from photographs of the casts in the library at the Blue Hill Observatory, near Boston, placed there by the founder, the late Professor Rotch. The casts are reproductions of the figures on the Tower of the Winds at Athens erected about 200 B. C.

the lowlands, for it is heavier, bulk for bulk, than warm air and unless prevented will roll itself to the bottom. The inclination of the valleys to the prevailing winds makes a difference. If the valleys are walled in so much the worse. The nature of the soil counts as well as the cover crop. Dark soils radiate more rapidly than light soils, while plowed and wet lands differ from unbroken and dry soils. Frost streaks are probably due to stagnant layers of cold air *resting* on chilled soils, for even a slow flow of the air will suffice to prevent frost. Crops on the hillsides escape for the double reason that the air is in motion and because the slopes front the level of warm air and, whatever flow there is, is from this warm level laterally to the slope.

FIG. 5—Sinuous frost effect.

We have said that the streams of cold air are very shallow—often only a few meters in depth. If we can divert or disturb these we can prevent the rapid cooling of the ground by radiation. How, then, shall we protect? A hint has been given above, namely to follow Nature. If we can not control the circulation, then spread a cover to conserve the earth heat. The cloud is the cover which Nature spreads, and even a light fleece will do the work, for there is no frost on cloudy nights, even when the clouds are high. Assuming that the agriculturist has been warned by the forecaster, what shall he do? Forewarned is forearmed, it is said; but not in this case unless the grower has prepared a supply of fuel, covering material, water, sand or fine ash, and has available labor. The easiest way

is to cover the plants with paper, cloth, straw, or mulch or make a cover of dense smoke by sprinkling water on small fires of brushwood soaked with oil. Or heat can be applied more directly by lighting many small fires or by using orchard heaters, which are metal containers holding about a gallon of crude oil. Large open fires are not effective because most of the heat goes into the higher levels, where it is not needed. The problem is to heat or displace a comparatively shallow stratum of air close to the ground. There is therefore no gain in having bonfires unless in some way a circulation can be established and warm air from above brought down. Unfortunately in most fields this is not the result, and the cold air is simply replaced by other cold air. The slight gain due to mixing and motion is not commensurate with the fuel used.

FIG. 6—Granular frost structure.

Another method is to mix the air or ventilate by blowers or windmills; but if there is much of a draft and the air is dry, some provision must be made for moistening. Other and more available methods involve the use of substances having a high specific heat, such as water, sand, or wood ashes. Of course flooding as practiced in the cranberry bogs is an old and effective preventive. On a smaller scale spraying with water that is moderately warm is good. A coating of ice does not necessarily result in injury, provided that both freezing and thawing are gradual.

For the average gardener or small fruit grower, however, the best method is that of covering. It is not exactly new, for our grandmothers knew enough to cover their favorite rose bushes, pinning paper over them and generally saving them. The one criticism is that the covering was easily displaced. The theory is simply that the heat waves re-emitted from the ground are intercepted by the cover, and the cooling of both ground and plant due to intensive radiation is stopped. It is wiser to use a more durable cover, preferably light waterproof material with proper fasteners. If

soil and plant are well watered before the cover is spread, so much the better. And finally it is an advantage to cover *early,* that is an hour or two before sunset rather than after. The method of direct heating has been used successfully in the fruit ranches of the West and Middle West; and about thirty oil pots to the acre will keep the temperature above freezing under average conditions.

Small growers as well as large growers can certainly save their crops from frost. In the aggregate the saving would be enormous.